*Volume 22* November, 1936 *Number 11*



# Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Metal Cutting
and the Selection of
Cutting Fluids

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

# TEXACO CHART FOR USE OF SOLUBLE AND CUTTING OILS

## ( BASED ON THE FOLLOWING GROUPS OF STEELS )

### GROUP No. 1

| | |
|---|---|
| Low Carbon Steels: | S.A.E. 1010, 1015, X-1015, 1020, X-1020, 1025, X-1025. |
| Free Turning Stock: | S.A.E. 1112, X-1112, 1115, 1120, X-1314. |

### GROUP No. 2

| | |
|---|---|
| Medium Carbon Steels: | S.A.E. 1035, 1040, X-1040, 1045, X-1045, 1050. |
| Manganese Free Turning Steels: | X-1330, X-1335, X-1340. |
| High Manganese Steels: | T-1330, T-1340. |
| Nickel Steels: | 2315, 2320, 2330, 2335. |

### GROUP No. 3

| | |
|---|---|
| High Carbon Steel (Tool Steels): | S.A.E. 1055, X-1055, 1065, X-1065, 1070, 1080, 1090, 1095. |
| High Manganese Steels: | T-1345, T-1350. |
| Nickel Steels: | 2340, 2350. |
| Nickel Chromium Steels: | S.A.E. 3120, 3130, 3140, 3150, 3220, 3230, 3240, 3250, 3312, 3325, 3340, 3415, 3435, 3450. |
| Molybdenum Steels: | S.A.E. 4130, X-4130, 4140, 4150, 4340, 4620, 4640, 4820. |
| | Molybdenum steels must be normalized and annealed to desired structure for machinability. |
| Chromium Steels: | S.A.E. 5120, 5140, 5150, 52100. |
| Chromium-Vanadium Steels: | S.A.E. 6120, 6130, 6140, 6195. |
| Tungsten Steels: | S.A.E. 71360, 71660, 7260. |
| Silicon Manganese Steels: | S.A.E. 9235, 9260. |
| Corrosion and Heat Resisting Steels: | S.A.E. 30905, 30915. |
| | These are the standard so-called 18-8 Chromium Nickel Stainless Steels. They are tough and stringy, and are somewhat difficult to machine. |
| | S.A.E. 51210 (Stainless Steel). (This steel can be machined at reduced speeds). |
| | S.A.E. X-51410 (Stainless Steel). (The high sulfur content makes this grade of stainless steel free machining.) |
| | S.A.E. 51335, 51510, 51710 (Stainless Steel). (These steels are difficult to machine). |
| Monel Metal: | |

### GROUP No. 4

Group No. 4 includes cast iron and malleable iron.

## NON-FERROUS METALS

| OPERATIONS | BRASS | COPPER |
|---|---|---|
| Cutting | No. 522 Oil | No. 3 Cutting Oil, or |
| Casting | No. 522 Oil | No. 522 Oil |
| | When high finish is required use 2 parts No. 522 Oil and 1 part No. 3 Cutting Oil. | Sultex Cutting Oil A or B can be used for threading if the parts are afterwards dipped in acid to remove the stain. |

| OPERATIONS | BRONZE | WHITE METAL |
|---|---|---|
| Cutting | No. 3 Cutting Oil | Texaco Kerosine |
| | Sultex Cutting Oil A or B can be used for machining hard bronze alloys. | |

CONTINUED ON INSIDE BACK COVER

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# Metal Cutting and the Selection of Cutting Fluids

A CUTTING tool in contact with any type of metal will be subject to friction when one or the other is set in motion for the purpose of shaping, forming or boring the metal by means of cutting away portions of it. This friction not only occurs at the cutting edge of the tool where the greatest pressure is exerted, but also between the face or side of the tool which is in sliding contact with the resultant chips or the groove, aperture or orifice during the course of cutting. The logical consequence is, therefore, the generation of more or less frictional heat dependent upon the pressures exerted, speed of operation, depth of the cut and hardness of the work. Were this allowed to continue with the probable resultant accumulation of heat, the cutting tool would suffer through a dulling of its cutting edge or alteration of its temper and hardness.

For this reason cutting tools must be kept cool, and in practically all cases lubricated to a more or less extent. More especially is this necessary by virtue of the high speeds and rates of production which must be maintained today. In other words, the fabrication of metal, such as drilling, turning, milling, shaping and grinding, can be performed more efficiently by the use of various substances known as "lubricants" and "coolants", but more correctly designated as "cutting fluids." These fluids are delivered to the tool at the cutting edge to give longer life, increased production and better surface finishes by enabling operation at higher turning speeds.

In the past there has been considerable difference of opinion as to whether cutting fluids should be termed lubricants or coolants. Of course, the question of tool cooling is decidedly important. On the other hand the fact that this development of heat is essentially the result of the occurrence of friction between not only the tool and work, but also within the latter due to the action of cutting, would seem to indicate that any reduction of this friction by means of a fluid film of lubricant could rightly be attributed to lubrication.

The extent, however, to which either would predominate would naturally depend upon the depth and nature of the cutting being performed. On the milling machine, for example, a cutting fluid will serve as a coolant and mild lubricant. A milling tool turns out a relatively short chip, commensurate, of course, with the character and hardness of the metal being cut. Furthermore, the depth of the cut is relatively uniform, therefore, there is not the necessity for forcing the cutting fluid to the point of contact of tool and work as is so often the case in drilling operations. The cooling action of air can, in consequence, be regarded as quite appreciable in the dissipation of frictional heat. While the product is not subject to severe duty on such work, its primary function nevertheless is to protect the cutting edge of the tool; were cutting to be done dry on any rel-

atively hard work overheating might readily occur even under the best of air conditions unless the operation can be performed in a current of cool compressed air, as is practiced in deep boring.

In drilling, on the other hand, as has been stated, it will be necessary to force the product to the innermost parts of the cut. This is frequently brought about by so designing the cutting tool that the fluid can be forced through it, being discharged directly at the point of cutting.

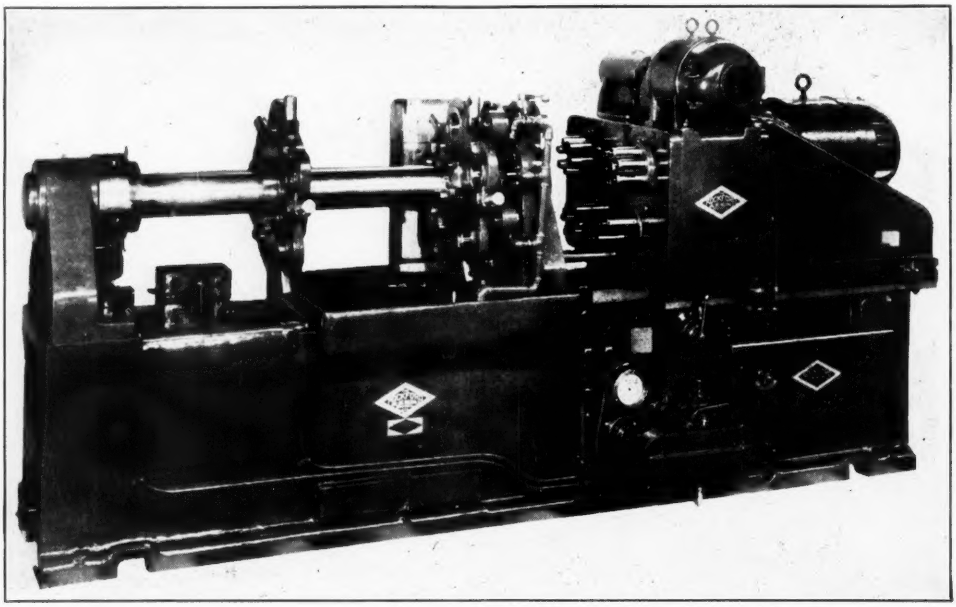
Here some feel that oftentimes it will be necessary for the fluid to possess lubricating as well as cooling characteristics, for frictional heat will not only be developed at the point of cutting but also in many cases along the shank of the tool. By directing the fluid to the cutting edge centrifugal force is taken advantage of, the lubricant and coolant being thrown outward to form a film between the work and tool. Furthermore, this aids in washing chips out from the aperture, serving thereby as an added protection against premature dulling or injuring of the tool.

To accomplish this more effectively pressure lubrication and cooling of cutting tools has been widely adopted. Obviously there is the added advantage in that flow of the cooling and lubricating medium can be accurately regulated and its delivery rendered practically automatic. The rate at which any such product is delivered to the cutting tool will, of course, be dependent upon the operating speed of the machine itself; the oil pump being directly connected to some moving part of the machine and thereby subject to the motion of the latter, although it does not operate as a rule at the same speed as that of the work spindle. Usually, the speed of the pump is constant. Oil is thus delivered only when necessary and there is little or no possibility for waste.

From an historical point of view it is interesting to note that about the year 1883, F. W. Taylor, the father of cutting oil research, demonstrated that when directing a heavy stream of water upon the cutting tool at the point where the chip is torn from the turning steel, the cutting speed could be increased from 30% to 40%.

Later, water and water-soda solutions became extensively used as coolants for cutting tools, and increases in production resulted wherever employed. They were not satisfactory in all cases, however, so further experimenting was done using oils of mineral, animal or vegetable origin. Delivery of these to the turning tool at the cutting edge gave better results than water or water-soda solutions in many cases. Of the above oils lard oil was found to be the most satisfactory medium for this purpose and it is still used by some manufacturers who regard it as the best lubricant for difficult machining operations.

With the development and introduction of mineral oils it was found that on lighter cutting operations and in the machining of brass,



*Courtesy of Rockford Drilling Machine Division of Borg-Warner Corporation*

Fig. 1—An hydraulic horizontal drilling machine of Rockford design. Flow of cutting fluid in this machine is automatic with the cutting movements of the tools.

such oils worked satisfactorily. On tougher and more difficult operations mineral oils, in turn, were blended with lard oil, the percentage of lard oil depending on the type of cutting operation. The most commonly known blends ranged between 10% and 40% lard oil and 90% to 60% mineral oil. These met cutting requirements for some time, but improvements in machine design enabling higher cutting speeds, and the development of better steel for cutting tools through increased hardness and toughness, indicated that the conventional blends of mineral-lard oils did not have the ability to absorb the additional heat developed in such improved service. Such oils also failed to lubricate the bearing surfaces between the chip and tool sufficiently to prevent wear and breakage.

To meet this condition, higher percentages of lard oils were first mixed with mineral oil and in a number of cases lard oil was even used straight. Due to the further advancement in manufacturing methods, the higher cost of the fatty oils, and gumming of machines, however, the addition of other ingredients to the mineral oils was studied. Exhaustive research has indicated that sulfur is the most generally satisfactory.

## CUTTING OPERATIONS

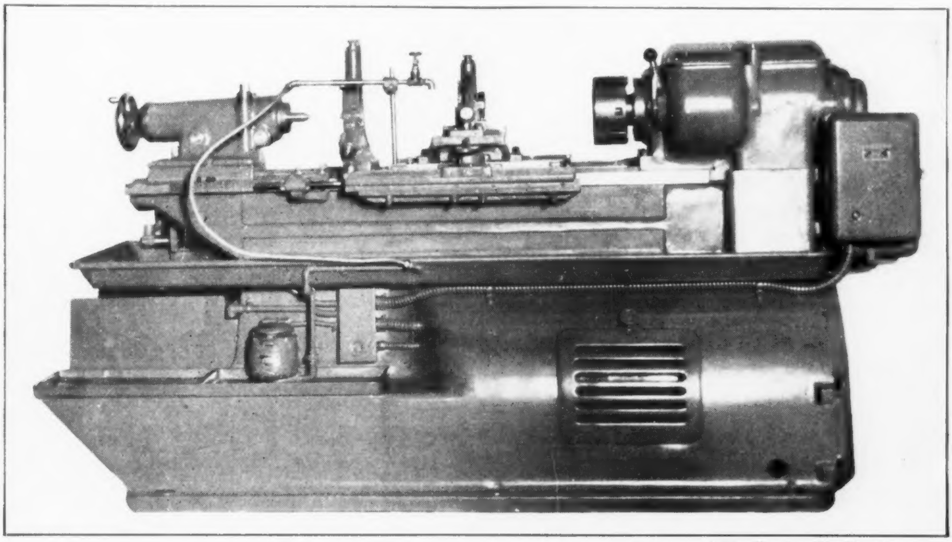
Machine operations wherein cutting fluids are required involve:

1. Turning and boring.
2. Drilling and reaming.
3. Shaping and planing.
4. Milling and hobbing.
5. Broaching.
6. Threading and tapping.
7. Grinding.

### Turning and Boring

Turning constitutes the removal of metal from external cylindrical surfaces. It is performed on engine lathes, turret lathes, automatics and some types of boring mills. Turning can also be performed on flat surfaces fastened to face plates, or held in chucks or collets.

Boring is the reverse of turning; i.e., the removing of stock from internal cylindrical surfaces. Even though it involves an interior instead of an exterior cut, boring can be performed on much the same type of machinery as turning by use of the proper type of cutting tool. This may require a single or multiple arrangement, the tools in turn being of shape to conform to the work.



*Courtesy of The Hendey Machine Company*

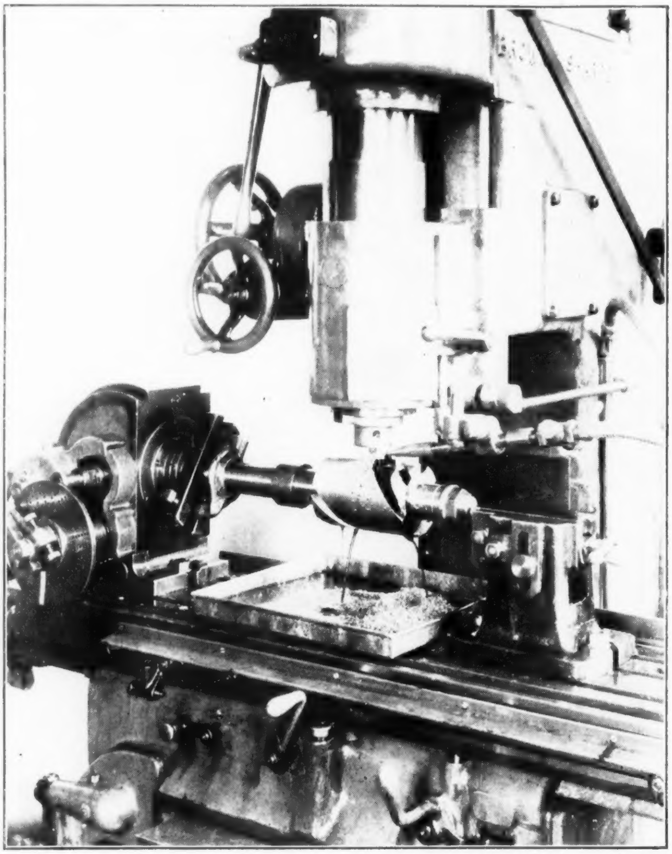
Fig. 2—View of the Hendey No. 3 Hi Speed Lathe. This illustration shows means provided for delivering the cutting fluid from the source of supply to the tool.

Lubrication of tool surfaces is most important in such service. the supply of cutting fluid, therefore, should always be ample to meet the requirements of the entire arrangement of tools as to lubrication and cooling. Sometimes, in order to accomplish this, it is necessary to install additional oil lines which will lead the cutting medium directly to each tool. The use of a suitable cutting fluid, correctly applied, will lead to reduction in production costs, increase in tool life, minimum spoilage and better surface finishes.

### Drilling and Reaming

Drilling is akin to boring in that it constitutes an operation of producing a circular hole by the removing of metal. Normally,

however, smaller diameters are involved. It is accomplished by revolving the drill as it is fed into the work. Two cutting edges cut away the metal, the spiral flutes helping to remove the chips from the hole.



*Courtesy of Brown & Sharpe Mfg. Co.*

Fig. 3—Gashing a helical milling cutter using a vertical spindle milling machine. Note point of delivery of cutting fluid.

Reaming is a finishing operation, being performed on the bored or drilled holes. It is done by means of a reamer which has several cutting edges. The amount of material removed by the reamer is small, thereby enabling it to produce a smoother, straighter and more accurate hole than is possible by either drilling or boring.

Drilling and boring of a hole are regarded as roughing operations, while reaming is a finishing process.

Cooling constitutes the chief function of a cutting fluid in drilling, along with the ability to wash away the chips. In deep hole drilling this latter function becomes more important, for the more effectually the chips are washed away the better chance will the cutting fluid have to reach the cutting edges of the drill and properly lubricate and cool the tool. If this is not accomplished the drill may become dull due to over-heating, and the surface finish will be irregular. Increased cooling of the drills by the cutting fluid is required as the holes are drilled deeper because of the lack of radiation. Again, by the selection and application of the proper cutting fluid, drill speeds and feeds can be increased and resharpening periods extended.

The requirements for a cutting medium on reaming operations are not as severe as in drilling, as the frictional heat developed is much less. Reaming being a finishing operation, better surface finishes are obtained when using a cutting fluid having adequate body and both cooling and lubricating characteristics. As in drilling, however, it is essential that the chips produced be rapidly washed away, for chip clearance may be very small and any binding of the reamer due to an accumulation of chips will scratch the surface and produce oversize holes. In rifle reaming chips can be most effectively washed away by delivering the cutting fluid to the cutting edges under pressure.

## Shaping and Planing

The removal of metal from flat surfaces by progressive parallel cuts is termed shaping or planing, depending on whether the work or tool is stationary. The operations are performed on machines known as shapers and planers.

The tool or cutter in the shaping operation is fastened to a reciprocating ram, the work being held by means of a vise, chuck, arbor or special fixture, which in turn is connected rigidly to the table. The table moves intermittently across the path of the cutter or tool.

The gear shaper is a special machine in which the principles of shaping are employed. In addition, however, the cutter is subjected to reciprocating motion, both cutter and work being rotated to produce correctly formed gear teeth. By using special cutters and altering the rotation of the cutter and work with respect to one another, almost any form of gear tooth can be obtained.

In the planing operation, in turn, the work is fastened rigidly to a reciprocating table or bed. Here the tool, which is fastened to a cross rail, is moved downward or across the work by an intermittent feed.

The duty involved in both planing and shaping depends, as in the case of turning and boring, on the depth of cut, the rate of feed, the

cutting speed and the type of material being machined. Cutting fluids for such service must, therefore, have ample lubricating ability and be applied in adequate volume to function effectively.

## Milling and Hobbing

Milling and hobbing involve the removal of metal by the use of milling cutters or hobs which are circular in shape, having a number of cutting edges spaced equidistantly on the circumference. The work is fastened to a table or bed and is fed against the revolving cutting tool. Milling cutters are rotated on vertical, horizontal or inclined spindles, the hobs being generally mounted and rotated on horizontal arbors.

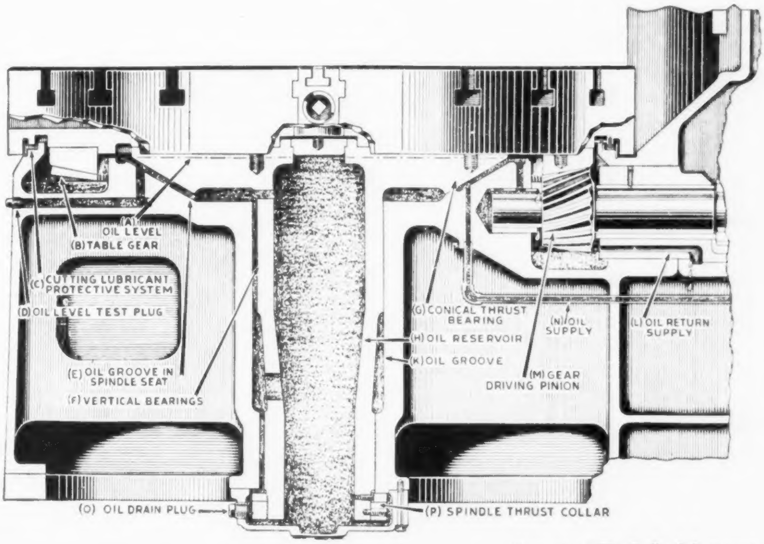
Hobbing machines are largely used for the cutting of gears, the correct tooth form being obtained by simultaneous rotation of the gear blank and hob. As in the operation of the gear shaper, it is possible to produce different forms by using specially designed hobs and changing the rotation of the latter with respect to the work.

The cutting action of the hob is such that should the cutting fluid have an abnormal excess of lubricating value over the amount required, it might allow the cutter edges to slide. This condition would greatly reduce the life of the tool. Furthermore, should the cooling effect of the cutting fluid be excessive, surface finish of some types of materials might be inferior. Demands for better surface finish and more accurate gear tooth shapes, therefore, make it essential for the selection of the cutting fluids for milling and hobbing operations to be given careful consideration, as the former must possess just the right balance between cooling and lubricating value to develop the desired results. This is determined by laboratory research and practical experimentation.

## Broaching

Broaching is the art of removing metal either externally or internally for the purpose of producing certain types of irregular shapes more economically than by milling, hobbing, boring, shaping or planing.

Broaching is considered as a severe cutting operation. It is performed by using a broach with cutting teeth of equal or irregular spacing, which progressively increase in height. The broach is drawn slowly down, either through the work for internal broaching, or over the surface to be broached in external broaching. Both the work and broach are rigidly held, allowing for no spring whatever.




*Courtesy of The Bullard Company*

Fig. 4—The spindle of a Bullard vertical turret lathe in detail, showing means provided for lubrication, and essential working elements.

Some broaching work is performed in two operations—roughing and finishing. Here the heat developed by the friction of the cutting action depends entirely on the depth of cut, or the amount of metal removed, the speed, the type of broach and the hardness of the metal. All will affect the tool life. Consequently, as the cost of the broaches are very high, it is important that the best tool life be obtained. This can only be accomplished by proper selection and application of the cutting fluid.

In some cases best results are obtained by increasing the volume and pressure of the cutting fluid in its application to the broach, thereby accelerating the washing and flushing away of the chips. This washing action is very important as any chips which may get between the broach and work will have an affect on the cutting edges and surface finishes.

## Threading and Tapping

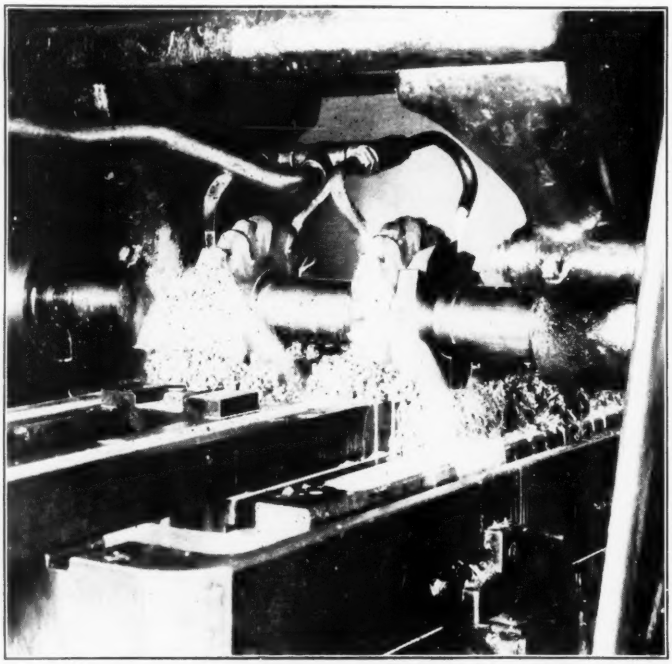
Threading constitutes the forming of an external screw thread by using a single tool, i.e., a die, chaser or hob.

Tapping is the forming of an internal screw thread by means of a tool known as a tap.

Threading operations are performed on thread milling machines, turret lathes, boring machines, screw machines and automatics. The work is held either by collets or chucks, or is

set between centers. The threading tools are mounted in their respective holders. Cutting is often performed in two operations; i.e., roughing and finishing.

In specially designed threading machines the work is fed into the threading tool which is mounted on a revolving spindle; this type of machine is adapted to high speed production.



*Courtesy of Brown & Sharpe Mfg. Co.*

Fig. 5—Milling special shaped grooves in a large machine part using specially formed cutters. The manner in which the cutting fluid is being directed to the working elements is of distinct interest.

The tapping operation is performed on turret lathes, automatics, screw machines, boring machines, drill presses of various types, and special nut tapping machines. In some cases the taps are held rigidly and the work is revolved and fed into the taps, in others the reverse is true. A floating holder is more satisfactory as it is claimed to lead to less tool breakage and less tendency for bell-mouthed tapped holes.

In any kind of threading work lubrication is the most important factor, cooling being secondary; consequently the selection of the proper cutting fluid and its subsequent application cannot be over-emphasized.

## Grinding

Grinding is performed by high speed grinding wheels which serve to remove the metal by abrasion. Grinding operations are performed on a variety of machines, such as cylindrical grinders, tool grinders, surface grinders, internal and centerless grinders. As the removal of metal by grinding is accomplished entirely by the abrasive action of the grinding wheel, high frictional heat is developed. This heat must be dissipated as soon as it is developed to insure good surface finish and to prevent distortion of the work, otherwise the accuracy of the finished parts might be affected. To insure best results the cutting medium, therefore, must have rapid cooling characteristics and must be free from any fatty matter or heavy material which might clog the pores of the grinding wheel. Occurrence of this latter would affect the cutting ability, cause increased friction between the work and wheel, and lead to development of excessive heat. The cutting fluid must also separate rapidly from grinding dirt so that the latter will not be recirculated; in this way a smooth and shiny finish free from scratches will be assured. The latter can be aided by filtration as well as precipitation of foreign matter.

To meet these requirements a cutting fluid for grinding should be a good coolant, free from fatty materials, have the ability to settle grinding dirt quickly, and protect the finished surface from rust and corrosion.

## FUNCTIONS OF A CUTTING FLUID

A cutting fluid is delivered to the turning tool and work to prolong tool life, increase production and to obtain better surface finish of the machined parts. To be satisfactory, such a product has, therefore, several functions to perform, depending on the nature of the material to be machined and the type of cutting operation. These will include two primary functions, viz.:

To dissipate heat, and

To lubricate.

Contingent upon these, the cutting fluid must:

Enable the cutting tool or grinding wheel to produce a satisfactory finish,

Prolong the life of cutting tools,

Prevent rust and corrosion, and

Carry and flush away turning chips and grinding dirt.

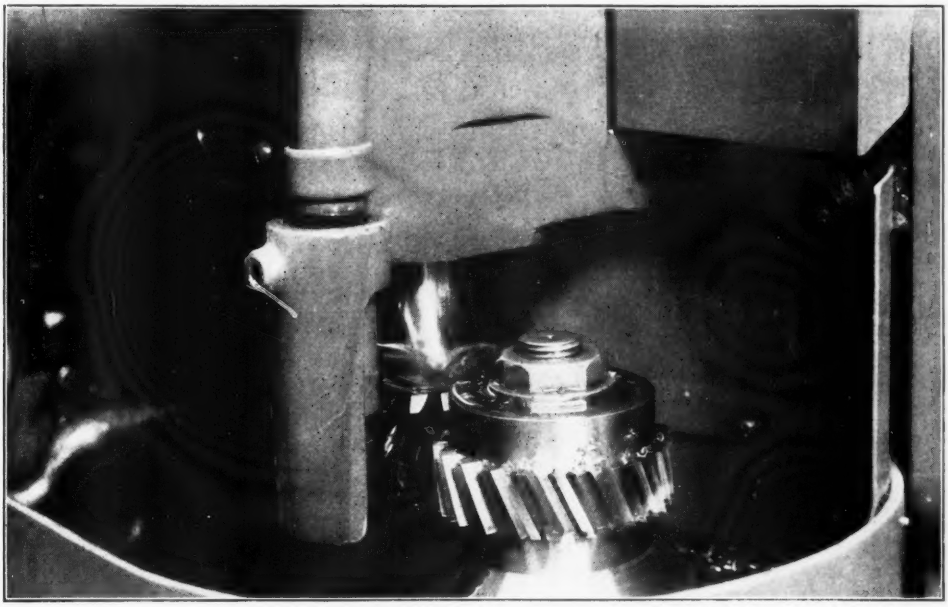
## Cooling

The action of a cutting tool in removing chips from the machined stock produces heat. Additional heat is also developed by the friction between the chip and the cutting surface

of the tool. This frictional heat varies according to the type of chip produced, the cutting speed, the feed and depth of cut. Should the metal being machined be of a brittle nature, the chip will break and crumble, causing but little frictional heat. On the other hand, should a long curled chip be obtained, as in the machining of some alloy and mild steels, the pressure and friction on the contact parts are extreme, producing high temperatures.

Control of the temperature of the cutting fluid, in turn, increases its heat dissipating and lubricating ability, with the added benefits of longer tool life, accuracy in machining, increased production and uniformity of the surface finish.

Another point to be considered is the expansion of the parts being machined. Unless the cutting fluid is functioning effectively they will become heated during the cutting process.



*Courtesy of The Fellows Gear Shaper Company*

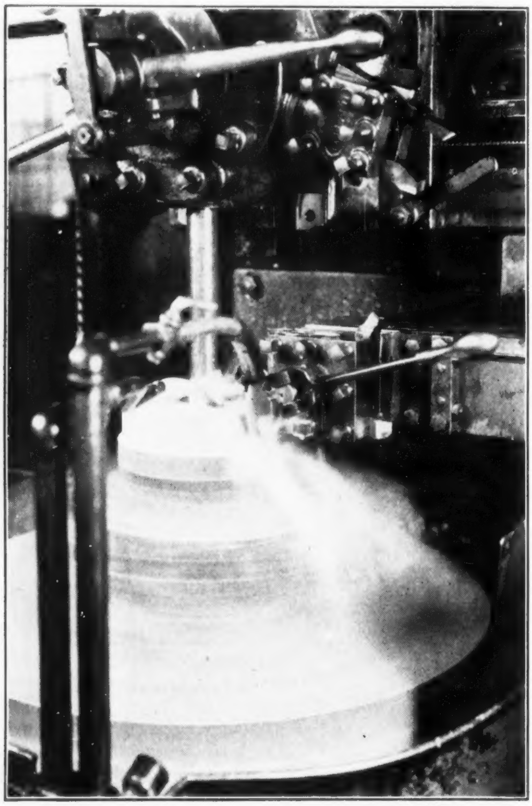
Fig. 6—Close-up view of a Fellows high speed gear shaper, showing the machine in operation with the cutting fluid flowing over the work and cutter.

Under such conditions should they be cut to size before being allowed to cool they would be undersized when removed from the machine. Obviously, therefore, to allow for atmospheric cooling before the final measurement is taken in order to develop the proper size, would slow up production and by so doing would increase the cost of the part. The introduction of carbides has presented a new angle to this problem, however, which is an advantage, viz.: tantalum carbide has a great faculty for carrying the majority of the heat to the chip, to thereby keep the work cool and reduce the tendency towards expansion, or change in diameter of cylindrical work.

The fact that overheating is oftentimes the most obvious difficulty has led to its being frequently regarded as the most detrimental. Opinion differs as to this, however, among many of the more progressive operators who are prone to regard lubrication as of equal importance. Yet this impression, during the earlier experimental stages through which the machine tool industry naturally passed, led to

The amount of heat generated in the turning operation also varies, for in the machining of harder and tougher steels more energy is required to remove the chip than in the machining of brass or low carbon steels. This increase in the amount of work done in removing the chip from tougher metals will obviously produce more heat, hence temperatures are increased by machining operations. If they are not controlled, extreme heat conditions may cause the cutting edge of the tool to be softened sufficiently to allow abnormal wear to occur, with the result that it will be necessary to grind more stock from the face of the tool when sharpening, thereby increasing tool costs. Tool failure can also be hastened where the chip has a tendency to crater a groove adjacent to the cutting edge. Softening of the tool, if not watched very closely, will also ruin the part being machined. Use of a properly prepared cutting fluid adapted to the type of metal to be cut, will materially reduce the above by serving as the medium for heat removal.

the use of water for the purpose of heat reduction. Water was cheap, easily handled and admirable for its heat abstracting characteristics. But water caused rust. Therefore, the addition of soda was adopted, for such mixtures apparently reduced the extent to which



*Courtesy of The Bullard Company*

Fig. 7—Close-up of a Bullard vertical turret lathe showing manner in which cutting fluid can be delivered in actual operation to develop maximum cooling and lubrication.

corrosion and rust formation occurred, and afforded a certain amount of lubrication. Still, their chief advantage was their cooling ability, though their relatively low cost was, of course, attractive.

Soda wash solutions are still used extensively in the grinding of steels, both work and grinding wheel being flooded continually. They are detrimental, however, in that they not only remove paint from any parts of the machine with which they come in contact, but also tend to cut the lubricant from any bearings or other wearing parts, thus being the potential cause of lubricating difficulties.

Water and soda solutions, likewise, are but poor makeshifts in the reduction of solid metallic friction. They may serve all very well in the removal of heat, but they do not have the viscosity to maintain the lubricating film which is often so necessary. For example, the continued occurrence of solid friction generates heat. Water or soda-wash solutions in turn remove this heat from tool and work if applied in sufficient volume, but friction usually continues. As a result, additional power must be consumed in the overcoming of this friction, provided production is not allowed to suffer. Any reduction of this friction could be expected to lead to greater production, increased tool life and a decrease in operating costs due to the higher cutting speeds and improved cutting.

It was, therefore, apparent that lubrication was entitled to consideration. So the soluble oils, from one angle, and lard oil from the other, came into usage. The former are most effective coolants, and on certain types of work today they are practically a necessity. In such products water is the essential component, therefore, it is still able to serve its original purpose as a tool coolant. In addition, the percentage of mineral oil, etc., which such a compound contains, is claimed to give the requisite amount of lubrication on work where tool cooling is the essential factor. Due to the high water ratio these products are furthermore inexpensive, easy to mix, and by reason of their low viscosity, readily freed of chips and other solid foreign matter. Therefore, they can be used over and over with but the necessity for a simple straining device to properly recondition them.

Certain authorities contend, however, that this matter of cooling is, after all, but a question of volume rather than any relative cooling ability. In other words, a lard or mineral oil, or a mixture of these two, or the use of a sulfurized mineral oil, could be expected to give the requisite results if supplied in sufficient volume and properly cooled and clarified after each circulation. In addition, the important feature of lubrication would be amply taken care of. So our modern cutting oils came into being.

## Lubrication

The lubricating requirements in the machining of cast iron, brass, white metals and some steels, are of little importance as the chip produced breaks into small pieces, which do not tend to clog the cutting edge, or else the material is removed in the form of dust. As but very little rubbing occurs between the tool and chip under such conditions, the main function of the cutting fluid is cooling.

The problem of lubrication becomes more important, however, as tougher metals are machined, especially those that produce a long chip that curls back over the lip of the cutting tool. This gives rise to considerable frictional resistance and presents a difficult point to lubricate; therefore, unless the cutting fluid can lubricate effectively, as well as perform the

essential functions of a coolant, the wear on the cutting surface of the tool may be considerable, causing short tool life and necessitating stopping of the machine for tool changes. Furthermore, unless the cutting fluid is an effective lubricant, metal-to-metal contact will probably develop with welding of the chip to the tool to form a bead which will increase the pressure on the cutting surface of the latter. The above can be materially reduced and tool life improved by applying means to break up the chips into small pieces.

Tools require resharpening because of the rubbing action of the tool against the work, the intensity of which depends upon the type of material and cutting operation which is being performed. Tool dullness with ordinary steels becomes more frequent when machining at higher speeds, being caused, as stated, by the heat produced by the rubbing of chip and tool to cause softening of the cutting edge. Consequently any restriction of the chip as it leaves the part being machined will definitely produce a poor surface finish.

It is, therefore, important when selecting a cutting fluid to make sure that the lubricating qualities will not be altered by the reclaiming process, as some oils are known to produce poorer results after being reclaimed and they can only be reused where the cutting operations are less severe. This is bothersome and expensive, and only by the careful consideration and selection of a cutting fluid can it be eliminated.

When oils were first adopted, lard oil was very extensively preferred. Lard oil by itself, however, is expensive when we consider the amount that is necessary to serve the average high speed cutting tool. Furthermore, unless of maximum purity it may tend to deteriorate, gum, turn rancid and decrease in its cooling ability with re-usage. Inferior grades of lard oil in addition may develop acidity, which is detrimental to the polished surfaces of both tools and work. Such deterioration also increases the hazards of infection, especially when low grade, inedible oils are used, a fact, which in the minds of many operators precludes its usage where personal safety is given prior consideration. Yet, lard oil, as a cutting fluid is decidedly advantageous by virtue of the relative smoothness of cutting which it makes possible.

Lard oil, therefore, should preferably be as low in free fatty acidity as possible, for the obvious reason that the occurrence of corrosion would thereby not be as probable. Furthermore, when lard oils are high in acidity they will decompose and turn rancid more readily, not only leading to premature gumming but also increasing the possibility of infection occurring, especially among careless or susceptible workers.

It can, therefore, be appreciated that while lard oil may be advantageous by virtue of its oiliness and the smoothness of cutting which it is claimed to give, it has certain disadvantages which must not be overlooked. For this reason it is not generally regarded as the most suitable product to use. Rather, straight mineral oils of low or medium viscosity (according to the material, speeds and cutting pressures developed), compounds of mineral and lard oils, or sulfurized mineral oils, are more usually preferred for all around service.

Mineral oils wherever they can be used without any compound have the advantage in that in all probability they can be made to serve as general machine lubricants as well; thereby facilitating storage and increasing the probability of better machine lubrication. In this connection it must be borne in mind that any product containing animal or vegetable oils (fixed oils) will oftentimes be prone to develop gumming and corrosion. Therefore, if it is by chance splashed onto machine wearing parts, or intentionally used as a lubricant, trouble may be experienced. The possibility of this, will, of course, be in more or less proportion to the amount of fixed oil present. Naturally a compound containing ten percent of prime lard oil would not be as apt to develop deposits, etc., as one containing perhaps forty per cent of a lower grade of such animal oil.

## The Matter of Satisfactory Finish

Having selected the proper oil with regard to its cooling and lubricating value, we must next consider surface finish. This is essentially a function of grinding. During this operation the chief duty of the cutting fluid is cooling. The emulsion must always have the ability to settle the products of grinding with great rapidity, otherwise if they become mixed with the emulsion, on being recirculated to the grinding wheel they will clog the wheel, making it necessary to dress the latter more often. This will increase wheel wear and the cost of the operation. Furthermore, when grinding wheels are clogged they will tend to produce an irregular and burnt surface finish.

The amount of cutting fluid delivered to the turning tool and grinding wheel has an effect on the surface finish, it having been proven that a considerable volume is conducive to best results. A large volume or flood of cutting fluid also insures against occasional dry cutting periods which are dangerous to all cutting tools.

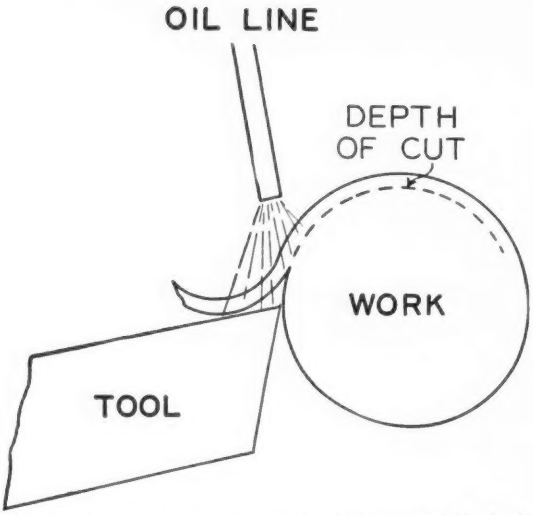



Fig. 8—Showing the correct manner in which cutting fluids should be applied to the tool and work in order that best results may be accomplished.

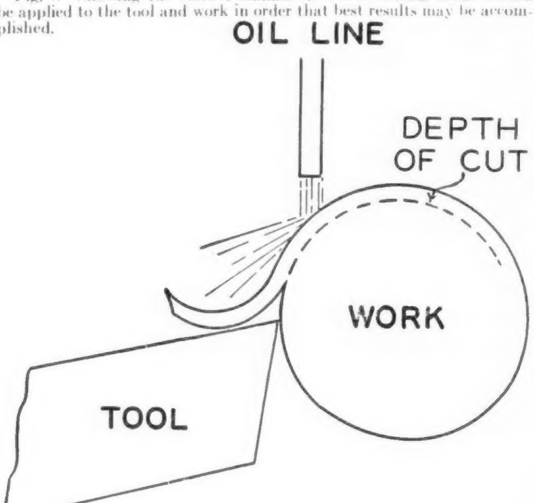



Fig. 9—In this view the cutting fluid may be deflected from the work and tool and thereby not be able to perform most effectively.

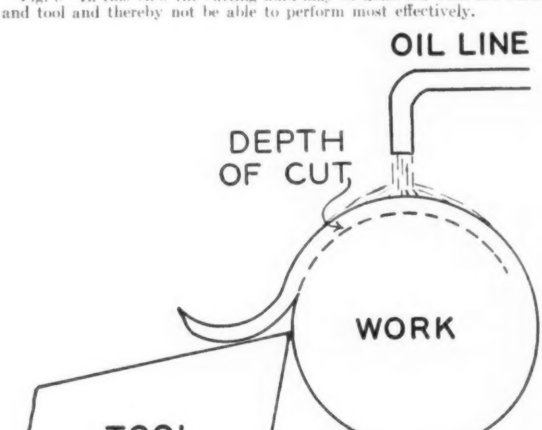



Fig. 10—When oil is applied in this manner, as indicated it can neither cool nor lubricate tool or work with any degree of satisfaction.

## To Prolong the Life of Cutting Tools

Tool life is defined in terms of the number of pieces machined between tool grinds. Therefore, the tool life can be increased by the proper selection and application of the cutting fluid and correct adjustment of the cutting rake. And yet, should the proper cutting fluid be purchased but then applied to the cutting tool improperly, poor results will be obtained.

Figs. 8 to 10 show the relative correct and incorrect methods of applying cutting fluid to the tool. In Fig. 8 the flow of cutting oil completely covers the tool, chip and working point, producing good cooling and lubrication. If, on the other hand, the oil is applied in a manner as indicated by Fig. 9 it may be deflected from the work and tool. In this application the volume is sufficient but the direction is incorrect, providing no cooling or lubrication to the tool, which undoubtedly will produce poor tool life. In Fig. 10, in turn, the amount of cutting fluid is inadequate to properly cool or lubricate the work and cutting tool, no matter how directed. Therefore, it is equally as important to apply the cutting fluid properly as it is to select the correct cutting medium.

## Prevention of Rust and Corrosion

In considering rust and corrosion it is well to remember that we must deal primarily with those factors which are the basic cause, viz., water and oxidation. The former is involved in any soluble oil or paste solution; the latter being the result of the use of unstable fatty oils in any mineral oil cutting preparation. Soluble oils or paste emulsions will usually require chief consideration. These range from 1 part of oil to 10 parts water, to 1 part of oil to 50 parts of water. The stability of inferior preparations of this nature may be slight, and should the emulsion be allowed to stand for any length of time breakdown and separation may result. The most injurious feature of this reaction is that the oil does not reach the tool and work evenly being scattered unevenly throughout the emulsion, instead of being uniformly distributed. As a result, where there is a predominance of water, rust spots may appear on the finished work. This will be accelerated by any marked increase in acidity which will be the result of breakdown in many of such preparations.

In some types of emulsions a rancid odor may be regarded as an indication of unstability. Any such product, therefore, should be discarded immediately. Under these conditions the tool life will be liable to be greatly decreased as the cutting emulsion passes to the tool in the same form as it reaches the work. The most effective soluble oil, therefore, is one that

forms a stable emulsion with water, and one which has the ability to maintain a cutting mixture of uniform oil dispersion. This will more positively prevent rusting, keep the cutting temperatures lower, and reduce tool cost by allowing more work to be done between tool grinds and dressing of grinding wheels. Likewise, the life of the emulsion will be increased considerably.

In the machining of brass and some types of bronze, should the cutting fluid contain lard oil with too high a percentage of free fatty acidity, dark spots or verdigris may appear on the machined surfaces. During stand-by periods even fungus-like deposits may appear. In most cases these will require additional machining or buffing for their removal.

### Removal of Turning Chips and Grinding Dirt

In cutting operations, such as deep hole drilling, milling and reaming, the ability of a cutting fluid to wash away the chips is a major requirement in order to obtain good tool life and surface finish. In deep hole drilling a properly ground drill will develop broken or disconnected chips; the cutting fluid, therefore, must be delivered under sufficient volume to completely flush the chips out of the hole. Any accumulation of metallic chips at the cutting edge of a drill will develop an abrasive action, which with continued operation will break down the cutting edges, interfere with circulation of the cutting fluid and prevent proper lubrication and cooling.

In reaming and milling operations, in turn, any accumulation of chips at the cutting edges of the reamer or milling cutter will produce inaccuracies and poor surface finish. Wedge action is particularly detrimental, for if chips become wedged between the cutting edges of the reamer and work they may produce oversize holes or cause scoring to affect the finish. Should this wedge action take place in milling the surface finish may show marks where the chips have been forced between the cutter and work; also the cutting edges of the milling cutter will show signs of rubbing under high pressure, necessitating grinding or resharpening of the cutter.

## TYPES OF CUTTING FLUIDS

The cutting fluids most extensively used today can be grouped under four headings:

1. Straight mineral oil.
2. Mineral lard oil.
3. Sulfurized
    - Mineral lard oil
    - Mineral oil
4. Soluble Oil.

### Straight Mineral Oil

Mineral oils are suitable for the light machining operations performed on some steels, for cutting brass, and for difficult operations such as tapping and threading of white metals. Straight mineral oils are also recommended where lubrication and cooling characteristics are necessary but where these requirements are not severe. Any such oil can be used in place of soluble oil emulsions where the machine design will not permit the use of a water emulsion. For example, in service where trouble might result were an emulsion to replace the lubricating oil in the bearings.

In selecting a straight mineral oil for tool cooling and lubrication, the matter of viscosity, body, or relative fluidity must be considered. As a general rule, unless "oiliness" is a decided factor, such an oil will be quite as suitable as a so-called cutting oil compound or soluble oil, provided it is of the right viscosity and is fed to the work in sufficient volume; furthermore, it will oftentimes be cheaper and will not develop abnormal acidity which might cause corrosion of the work or tool.

As already stated, one of the important features of a tool coolant and lubricant is its ability to separate from chips and other foreign matter. As a result, the heavier or more viscous the oil, the less rapidly will such separation occur, therefore, more time would be necessary, thus reducing the rate of oil circulation. This would necessitate a greater volume of oil. In addition, the heavier the oil, the more slowly will heat be carried away. It is generally best, therefore, to use an oil of as low a viscosity as possible, commensurate with such machine lubricating requirements as may be involved.

### Mineral-Lard Oil

Under operating conditions requiring a cutting fluid of greater lubricating value, mineral-lard oils are used. The percentage of lard oil necessary in the blend will depend on the depth of cut, the cutting speed, the feed and the type of chip; the latter will give a fair indication as to the degree of lubrication required. In general, from 10 to 40 per cent of lard oil will be used, the amount being increased with increase in hardness of the stock, or where deep cutting is essential.

Mineral-lard oils are used quite extensively in automatic screw machines where a better surface finish is required than could be obtained by using a straight mineral oil. Their adaptability to tool cooling and lubrication in machine tool cutting today is explained by the fact that they possess that certain degree of "oiliness" so necessary to lubrication, along with relatively low viscosity. This not only

accelerates the rate of heat transfer, but also enables ready separation from chips and foreign matter.

In preparing a mineral-lard cutting oil, storage and operating temperature requirements should always be taken into consideration. For example, it is a well known fact that lard oil has a relatively high pour test, therefore, it will tend to solidify when subjected to lower temperatures. The mineral oil base should in consequence have a sufficiently low pour test to insure that the resultant product will not tend to congeal prematurely when allowed to stand in a cold shop overnight. Furthermore, this oil should have a sufficiently high flash point to prevent abnormal vaporization at the temperatures of cutting.

## Sulfurized Oils

Sulfur, when added correctly to mineral oils or mineral-lard oils, increases their cooling and lubricating characteristics, and helps to prevent welding of the chip to the tool. Sulfurized oils also have the ability to penetrate to smaller crevices than lard or fixed oils. This ability, plus added film strength, gives better surface finishes even though some steels may be more difficult to machine. For this reason sulfurized oils are continually gaining in usage when machining medium, high carbon and alloy steels. These oils are also ideally suited to threading operations on all types of steel. Highly sulfurized oils, however, are not suitable for the machining of brass or non-ferrous alloys owing to the corrosive action of the sulfur, which turns the surfaces of these metals black.

## Soluble Oils

Cutting oils, however, whether they involve straight mineral lubricants, lard oil combinations or sulfurized products, have a relatively low ability to absorb and transfer heat away from the cutting tool as compared with water or water solutions. Therefore, inasmuch as there are numerous classes of work where cooling action is more important than lubrication, it is evident that some solution or emulsion containing a relatively high percentage of water must be used. Of course, where cutting is done under lower operating speeds, or where light or medium cuts on softer materials are to be made, the action of cooling may not require so much consideration, even though the nature of the operation would be such as to usually involve a coolant. But where milling, boring or grinding of such materials as alloy or high speed steels is involved, so much heat will usually be developed under average conditions that provision must be made to keep the tool cool, otherwise it may become prematurely dulled or damaged, with the result that the rapidity of cutting will be reduced and production materially affected. This requires the use of soluble oils, capable of forming permanent emulsions with water, which will possess high cooling ability. They must also be free from mineral acids, have no disagreeable odor and contain no ingredients that may be injurious to the workman's hands; the resultant emulsion also must show minimum tendency to gum or clog the mechanism of the turning or grinding machines.

An emulsion for grinding is normally much leaner than for machining operations. The solution for turning ranges from one part oil with ten parts water, to one part oil with thirty parts water, while the grinding emulsion may reach a ratio of one part oil to 50-60 parts water. Soluble oil mixed in a ratio of one part oil to 2-5 parts water has in turn given satisfactory results in shallow drawing of metals.

The emulsion in normal machining service is mostly used on roughing operations where the surface finish is not of major importance. The surface finish being improved by a grinding operation later in the production schedule.

Soluble oils are mixtures of oils with soluble emulsifying agents, such as soaps, alcohols or other specific materials which will keep the mineral oil in permanent suspension when mixed with water. Soluble oils are relatively fluid, and contain a considerable percentage of mineral oil. Pastes or compounds, on the other hand, are more of the consistency of grease. The former are most generally used. Both are designed, however, for mixture with water preparatory to usage although certain so-called cutting compounds can be used in their marketed form.

A soluble product for cutting tool usage should be so prepared as to be readily miscible with either warm or cold water, and capable of forming and maintaining perfectly emulsified solutions under continued usage. Separation of any of the products is just as objectionable in machine tool work as separation of greases in general plant lubrication. In other words, both the cooling and lubricating ability of the product would thereby be materially affected.

Properly prepared soluble oils are claimed by many operators to be adapted to a wide range of cutting in the average shop or tool room. In other words, with a properly compounded and emulsified soluble solution, heat will be abstracted from the cut and tool at more nearly the desired rate, due to the water content; rusting and corrosion will be usually prevented due to the oil content, and lubrication will be attained, also, the possibility of acidity, oxidation and gumming will be remote.



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CONTINUED FROM PAGE ONE

# Texaco Chart for use of Soluble and Cutting Oils

## IRON AND STEEL

| OPERATIONS | GROUP No. 1 | GROUP No. 2 |
|---|---|---|
| Grinding | 50 parts Water<br>1 part Soluble Oil C | 50 parts Water<br>1 part Soluble Oil C |
| Cold-Sawing (High Speed), Band Hack, or Circular Saws | 30 parts Water<br>1 part Soluble Oil C | 30 parts Water<br>1 part Soluble Oil C |
| Cold-Sawing (Low Speed) | Sulfur Cutting Oil A-4, or<br>No. 3 Cutting Oil | Sulfur Cutting Oil A-2, or<br>No. 3 Cutting Oil |
| Hobbing, Milling and Drilling | 20 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-4, or<br>No. 3 Cutting Oil | 15 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-2, or<br>No. 3 Cutting Oil |
| Planing, Shaping, Boring and Turning | 30 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-4, or<br>No. 3 Cutting Oil | 20 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-4, or<br>No. 3 Cutting Oil |
| Reaming | 15 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-2, or<br>No. 3 Cutting Oil | 10 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-2, or<br>No. 3 Cutting Oil |
| Broaching (Roughing)<br>Up to 1" Broach | 20 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-4, or<br>No. 3 Cutting Oil | 15 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-4, or<br>No. 3 Cutting Oil |
| Broaching (Roughing)<br>Over 1" Broach | 15 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-2, or<br>No. 3 Cutting Oil | 15 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-2, or<br>No. 3 Cutting Oil |
| Broaching (Finishing)<br>Up to 1" Broach | Sulfur Cutting Oil A-2, or<br>No. 3 Cutting Oil | Sultex Cutting Oil A |
| Broaching (Finishing) Over 1" Broach | Sultex Cutting Oil A | Sultex Cutting Oil A |
| Broaching (Finishing) Heavy Duty | Sultex Cutting Oil B | Sultex Cutting Oil B |
| Die Threading and Tapping | Sulfur Cutting Oil A-2, or<br>No. 3 Cutting Oil | Sulfur Cutting Oil A-2, or<br>Sultex Cutting Oil A |
| Pipe Threading and Automatic Tapping Machines | Sultex Cutting Oil B | Sultex Cutting Oil B |

| OPERATIONS | GROUP No. 3 | GROUP No. 4 |
|---|---|---|
| Grinding | 50 parts Water<br>1 part Soluble Oil C | 50 parts Water<br>1 part Soluble Oil C |
| Cold-Sawing (High Speed), Band, Hack, or Circular Saws | 20 parts Water<br>1 part Soluble Oil C | 10 parts Water<br>1 part Soluble Oil C |
| Cold-Sawing (Low Speed) | Sulfur Cutting Oil A-2, or<br>No. 3 Cutting Oil | 20 parts Water<br>1 part Soluble Oil C |
| Hobbing, Milling and Drilling | 10 parts Water<br>1 part Soluble Oil C, or<br>Sultex Cutting Oil A | 30 parts Water<br>1 part Soluble Oil C |
| Planing, Shaping, Boring and Turning | 20 parts Water<br>1 part Soluble Oil C, or<br>Sultex Cutting Oil A | 40 parts Water<br>1 part Soluble Oil C |
| Reaming | 10 parts Water<br>1 part Soluble Oil C, or<br>Sultex Cutting Oil B | 20 parts Water<br>1 part Soluble Oil C |
| Broaching (Roughing)<br>Up to 1" Broach | 10 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-2 | 10 parts Water<br>1 part Soluble Oil C |
| Broaching (Roughing)<br>Over 1" Broach | 10 parts Water<br>1 part Soluble Oil C, or<br>Sultex Cutting Oil A | 10 parts Water<br>1 part Soluble Oil C |
| Broaching (Finishing)<br>Up to 1" Broach | Sultex Cutting Oil A | 10 parts Water<br>1 part Soluble Oil C |
| Broaching (Finishing)<br>Over 1" Broach | Sultex Cutting Oil B | 10 parts Water<br>1 part Soluble Oil C |
| Broaching (Finishing)<br>Heavy Duty | Sultex Cutting Oil B | 10 parts Water<br>1 part Soluble Oil C |
| Die Threading and Tapping | Sultex Cutting Oil B | **Cast Iron:**<br>10 parts Water<br>1 part Soluble Oil C<br>**Malleable Iron:**<br>10 parts Water<br>1 part Soluble Oil C, or<br>Sulfur Cutting Oil A-2 |
| Pipe Threading and Automatic Tapping Machines | Sultex Cutting Oil B | |